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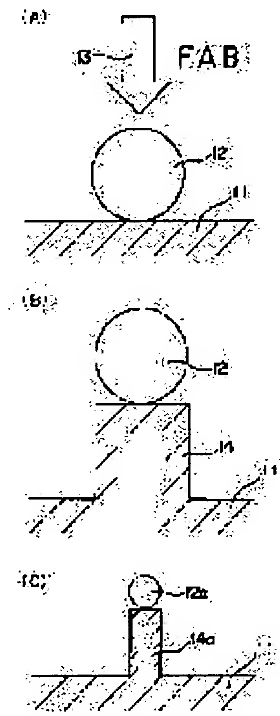
(54) ENERGY BEAM PROCESSING METHOD

(57)Abstract:
PURPOSE: To perform fine processing on the order of dimensions of fine particles by dispersing the fine particles of a specified diameter on the surface of a material to be processed and applying an energy beam.
CONSTITUTION: Fine particles 12 of cobalt, zinc, ferrite, etc., the diameter of which is selected from 0.1-10nm, 10-100nm, 1000nm-10μm are dispersed on the surface of a specimen 11 of GaAs, Si, glass, etc., which is a material to be processed. The fine particles 12 are mixed with a surfactant into a solvent such as ethanol, and the specimen 11 is immersed in the solvent with stirring, or the solvent is dropped on the surface of the specimen 11 and dried to make the fine particles 12 adhere to the surface of the specimen 11 uniformly. Next, the specimen 11 is irradiated vertically with a high speed atomic beam 13 which is an energy beam so that only places which are not covered by the fine particles 12 are processed by the beam 13, leaving rod-shaped structures 14 in places which are covered with the fine particles 12 and shielded from the beam 13.



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μ-shielding mask
vertical FAB

CLAIMS

[Claim(s)]
[Claim 1] The energy beam processing method characterized by for the diameter which covers an energy beam on the surface of a workpiece distributing a particle (0.1nm, 10nm, 10nm, 100nm, 100nm, or 10 micrometers), irradiating an energy beam at the aforementioned workpiece, and processing the aforementioned workpiece front face except the covered part by the aforementioned particle.
[Claim 2] The energy beam processing method according to claim 1 which carries out diameter reduction processing of the aforementioned particle gradually by irradiation of the aforementioned energy beam while processing this workpiece front face in the depth direction, and is characterized by processing the cylindrical structure of a taper into the covered part of this particle.
[Claim 3] The claim 1 characterized by making ** - distribute the aforementioned particle mostly with a surface active agent in solvents, such as ethanol, making a solution, dropping this solution at a workpiece front face, or dipping a workpiece into this solution, distributing the aforementioned particle on a workpiece front face at ** -, and irradiating an energy beam at this workpiece, or the energy beam processing method of two given in any 1 term.
[Claim 4] The claim 1 to which the aforementioned particle is characterized by being the ultrafine particle of a ferrite, cobalt, zinc, and a diamond, or 3 is not, but it is the energy beam processing method given in ** 1 term.
[Claim 5] A magnetic field, electric field, or laser is made to act on the particle on the aforementioned front face of a workpiece, and the claim 1 characterized by carrying out the configuration control of this particle according to a processing pattern or 4 is not, but it is the energy beam processing method given in ** 1 term.
[Claim 6] The claim 1 to which the aforementioned workpiece is characterized by being the semiconductor material of III-V group systems, such as GaAs, InAs, AlGaAs, and InGaAs, or the energy beam processing method of five given in any 1 term.
[Claim 7] The claim 1 characterized by the aforementioned workpieces being Si content semiconductor materials, such as Si and SiO2, or the energy beam processing method of five given in any 1 term.
[Claim 8] the energy beam processing method which is the any 1 term publication of the claim 1 characterized by the processed workpiece generating the quantum effect, or the 7th term
[Claim 9] The claim 1 characterized by introducing the gas particle which shows chemical reactivity to this workpiece into the workpiece which irradiated the energy beam and performed micro processing, controlling the chemical reactivity on this front face of a workpiece to it by the temperature control, and processing this workpiece front face into it isotropic, or the energy beam processing method of eight given in any 1 term.
[Claim 10] The claim 1 to which the aforementioned energy beam is characterized by being the high-speed atomic line, an ion beam, an electron ray, laser, synchrotron orbital radiation, or an atom and a molecular beam, or the energy beam processing method of eight given in any 1 term.

[Translation done.]

* NOTICES *

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Industrial Application] this invention distributes a particle on a workpiece front face, irradiates an energy beam, and relates to the energy beam processing method for having been made to perform micro processing from the size order of a particle, or the size of a particle to minute size order.
[0002]
[Description of the Prior Art] The role with the important photolithography technology using the photoresist mask of a configuration aligned with the processing pattern of a substrate was come for substrate processing in a semiconductor process sure enough. In substrate processing by photolithography technology, etching processing is given to the portion which covers the portion which is not processed on a substrate with a photoresist mask, and is not covered with a photoresist mask, and the depth according to floor to floor time is processed.
[0003] what shows the example of a process of the conventional micro-processing method a photoresist mask is used for drawing 8 -- it is -- this drawing (A) - (E) -- the 1- each 5th process is shown In the 1st process, the processing substrate 1 is first coated with the resist material 2. Next, in the 2nd process, a photo mask 3 is made to intervene, ultraviolet rays 4 are irradiated at the resist material 2 of processing substrate 1 front face, and pattern hole 3a formed in the photo mask 3 is imprinted to the resist material 2. Next, in the 3rd process, the resist material 2 of the portion in which ultraviolet rays 4 were irradiated by development through pattern hole 3a is removed, and it leaves only a required photoresist film. At the 4th continuing process, the ion and radical kind in plasma are used, anisotropic etching is given to a portion without the resist material 2 on the processing substrate 1, and the resist material 2 is removed in the last process [5th]. As mentioned above, micro processing which forms hole 1c of the same shape as pattern hole 3a of a photo mask 3 in the front face of the processing board 1 through the 1st - the 5th process is performed. in addition -- a general semiconductor device -- above-mentioned the 1- forming two or more holes where the depth differs usually comes out on the processing substrate 1 by carrying out by repeating about the 5th line
[0004]
[Problem(s) to be Solved by the Invention] The micro-processing method using the above-mentioned conventional photolithography technology was not what must be ready for loss considerable also in cost also in time, and can be applied easily [micro processing of a nano meter scale] when special equipment and a special device are needed, in order the photo mask 3 which has the complicated photoresist pattern of manufacture process is indispensable and to process this photoresist pattern into the line breadth or the path below lmum moreover. Moreover, the resist material 2 had limit that it could not be used, when an usable material will be restricted naturally and the resist material 2 became a contamination component, since exposing to ultraviolet radiation or an electron ray was an indispensable condition. Furthermore, since the surface degree of **** or surface granularity were not able to irradiate ultraviolet radiation to a crude sample about photoresist film production at ** -, it was uniform and accurate resist film attachment was difficult.
[0005] Moreover, even though it processed pattern structure below lmum using the conventional plasma process, there were many particle numbers of the energy particle which carries out oblique incidence under the influence of the collision of a gas particle, the charge up of resist material, etc., for this reason, it was perpendicular, processing of a tall fine structure object, i.e., high processing of an aspect ratio (ratio of structure width of face to the processing depth), was difficult, and the width of face of the structure of most processings below lmum was unreasonableness.
[0006] Therefore, by the purpose of this invention distributing a particle on a workpiece front face, and processing it by irradiating an energy beam Are in making micro processing of a nano meter scale possible, make a magnetic field, electric field, or laser act if needed, and the configuration control of the particle is carried out. After irradiating an energy beam furthermore, isotropic processing is given in a chemical reactivity gas particle or a solution, and it is more detailed and is in manufacturing the high structure of an aspect ratio.
[0007]
[Means for Solving the Problem] The diameter which covers an energy beam on the surface of a workpiece distributes a particle (0.1nm, 10nm, 10nm, 100nm, 100nm, or 10 micrometers), and this invention irradiates an energy beam at the aforementioned workpiece, and attains the aforementioned purpose by offering the energy beam processing method characterized by processing the aforementioned workpiece front face except the covered part by the aforementioned particle.
[0008] Moreover, the thing for which it carries out diameter reduction processing of the aforementioned particle gradually by irradiation of the aforementioned energy beam while this invention processes this workpiece front face in the depth direction, and

the cylindrical structure of a taper is processed into the covered part of this particle, Or make ** - distribute the aforementioned particle mostly with a surface active agent in solvents, such as ethanol, and a solution is made. The aforementioned purpose is attained by dropping this solution at a workpiece front face, or dipping a workpiece into this solution, distributing the aforementioned particle on a workpiece front face at ** -, and offering the energy beam processing method characterized by irradiating an energy beam at this workpiece etc.

[0009] Furthermore, the thing which this invention makes a magnetic field, electric field, or laser act on the particle on the aforementioned front face of a workpiece, and is done for the configuration control of this particle according to a processing pattern, Or the gas particle which shows chemical reactivity to the workpiece which irradiated the energy beam and performed micro processing to this workpiece is introduced. The aforementioned purpose is attained by controlling the chemical reactivity on this front face of a workpiece by the temperature control, and offering the energy beam processing method characterized by processing this workpiece front face isotropic etc.

[0010]

[Function] According to this invention, with the conventional photolithography technology, micro processing with difficult realization becomes possible by processing the aforementioned workpiece front face except the distributing particle of nano meter scale mostly, irradiating energy beam at aforementioned workpiece, and according to aforementioned particle cover part which covers an energy beam on the surface of a workpiece.

[0011]

[Example] Hereafter, the example of this invention is explained with reference to drawing 1 or drawing 7 . Drawing 1 is process drawing showing one example of the energy beam processing method of this invention.

[0012] As shown in drawing 1 (A), cobalt with a diameter of 5nm - about 1 micrometer, Zn (zinc), and the particle 12 of a ferrite are distributed on the front face of the samples 11, such as GaAs and Si which are a candidate for processing, and glass. A particle 12 can be made to adhere to the front face of a sample 11 uniformly by dipping a sample 11 into the solution which this distribution was made by adhesion, and mixed and agitated the particle 12 with the surface active agent in solvents, such as ethanol, and specifically became a uniform concentration part city, or making the front face of a sample 11 trickle and dry a solution. In this way, the particle 12 which covers an energy beam is uniformly distributed by the front face of a sample 11 with a probable precision.

[0013] Next, a sample 11 is mostly irradiated at a perpendicular along the direction which showed the high-speed atomic line 13 which is an energy beam to drawing 1 (A) by the arrow. In order that the part covered by the particle 12 at this time may cover the high-speed atomic line 13, only the part which is not covered by the particle 12 is processed by the high-speed atomic line 13, and processing shown in drawing 1 (B) advances.

[0014] However, in order that processing by the high-speed atomic line 13 may attain to not only the sample 11 but the particle 12, diameter reduction processing of the particle 12 is strictly carried out gradually with advance of irradiation. However, configuration change of this particle 12 changes with reactivity with the gas used for the high-speed atomic line 13. Then, in order to realize processing of a high aspect ratio, to rare gas or a particle 12, reactivity is low, and the processing method which suppresses configuration change of a particle 12 as much as possible is adopted here using the high-speed atomic line 13 which serves as a sample from reactant high gas. Consequently, while it has been raw as a cylindrical perpendicular wall, it can leave only the part where the particle 12 adhered. In this way, for the cylindrical structure 14 left behind to the front face of a sample 11, nothing and particle size are ** about the cylindrical fine structure which has a 5nm - 1 micrometer diameter of a cross section according to the size of a particle 12. - Equalization of a configuration is put into practice, so that a particle 12 is used.

[0015] In addition, by introducing particles, such as a sample 11, reactant high gas, for example, chlorine gas, and fluorine gas, into the sample 11 which gave the above-mentioned energy beam processing, and heating a sample 11 by the heater or the heat lamp, as shown in drawing 1 (C), legal processing, such as not having directivity, can be given. By giving this ** legal processing, when reduction processing is carried out by the constant ratio and not only the remains particle 12 but the cylindrical structure 14 is compared with processing only by the high-speed atomic line 13, cylindrical structure 14a which has a more detailed cross-section configuration can be made. Moreover, since it is unnecessary, as for particle 12a which finally remained, it is good in many cases, for ultrapure water water jet washing etc. to remove from the crowning of cylindrical structure 14a.

[0016] By the way, as a sample 11 used for the above-mentioned energy beam processing, all material, such as substrates, such as GaAs of a semiconductor material, and Si, SiO_2, or the glass of an insulator and a ceramic, and also a metallic material, can be used. Moreover, as for a particle 12, it is good to use ultrafine particles, such as a ferrite, zinc, cobalt, and a diamond, when an ultrafine particle 0.1 micrometers or less is required, and when the particle size of 0.1-10 micrometers is required, it is good [a particle] to use the particles 12, such as an alumina, graphite, a golden particle, and a silver particle. Furthermore, when choosing these particles 12 in respect of the quality of the material, it is good to use the thing of the suitable quality of the material in consideration of reactivity with a reactant gas particle, a spatter property, etc.

[0017] In addition, in the above-mentioned example, the energy beam processing method of a particle which showed the processing process in drawing 2 (A) - (E) as an example as for rare gas reactivity is high, and this differs from a substrate a little although reactivity suppressed the reactivity of an energy beam and a particle 12, using the high-speed atomic line 13 of low gas as an energy beam is also significant. This processing method expects configuration change of the particle by the energy beam itself to some extent, and it uses for the high-speed atomic line 23 of chlorine gas a diamond ultrafine particle with a particle size of 1nm - 50nm which shows reactivity as a particle 22 here while the high-speed atomic line of chlorine gas is further used for it as the high-speed atomic line 23, using the semiconductor material of III-V group systems, such as GaAs, AlGaAs, and InAs, as a sample 21.

[0018] First, as shown in drawing 2 (A), the diamond ultrafine particle 22 is distributed on the front face of a sample 21, and the high-speed atomic line 23 of chlorine gas is irradiated in the direction of an arrow. Although processing of sample 21 front face advances by this as shown in drawing 2 (B) and (C), the diamond particle 22 is also gradually processed with a working speed later simultaneous again than it. In order to also reduce the cover area of the diamond particle 22 to the high-speed atomic line 23 in connection with the diameter of the particle size of the diamond particle 22 being reduced, the sample 21 of the portion covered by the diamond particle 22 is processed into the cylindrical structure 24 of a taper as shown in drawing 2 (D). In the example, since it is made to continue beam irradiation until the diamond particle 22 disappears, as finally shown in drawing 2 (E), the cylindrical structure 24 of a taper with which the steeple, i.e., a nose of cam, sharpened is realized. Incidentally, the cylindrical structure 24 actually manufactured by this processing method was what it equips with aspect ratio with as sufficient height as about 250nm with 10nm although the path at a nose of cam is detailed.
[0019] In addition, since it is further radicalized in the nose of cam of the cylindrical structure 24 after energy beam processing, it is also possible by introducing only chlorine gas after beam irradiation and heating a sample 21 with a heater or the lamp for heating like the aforementioned example, to give isotropic processing. In this case, the cylindrical structure 24 is further processed into the 0.1nm - 5nm diameter of a nose of cam of a taper. Moreover, it is effective, especially when chemical reaction surface treatment by heating is performed, an effect is in surface smoothing or removal of a damage layer and the quantum effect element is manufactured in this way, after irradiating the high-speed atomic line. Shift a property which is different from the bulk property which a microstructure has with the quantum effect, for example, the wavelength of light, to a short wavelength side, or When bulk shows a shift and ****** to a different short wavelength side or the light which points out the effect which shows the property of changing level of electronic energy, for example, is emitted from the cylindrical structure, and a laser beam make the cylindrical structure pass a laser beam It is possible to amplify the intensity of a laser beam in a laser beam shifting to a short wavelength side according to the quantum effect.
[0020] Drawing 3 and the workpieces 30 and 40 shown in 4 show the example of processing at the time of arranging a particle regularly at a 2-dimensional flat surface, and performing energy beam processing. That is, the workpiece 30 shown in drawing 3 arranges a colonnade 34 according to a predetermined arrangement pattern (matrix arrangement pattern) as the cylindrical structure on the front face of a sample 31, and the workpiece 40 shown in drawing 4 arranges a cone 44 by the predetermined matrix arrangement pattern as the cylindrical structure on the front face of a sample 41. It can be said that the method of processing it in this case is the point of using an operation of laser, electric field, or a magnetic field for the configuration control of a particle 32, and forcing a regular distribution array into the cylindrical structure (a colonnade 34 and cone 44) from a probable distribution array, and is the more advanced processing method although the above-mentioned beam irradiation is followed fundamentally. In order that laser may make particle 32 irradiated the very thing ionize, or may make the circumference of a particle 32 ionize and may form plasma, the particle 32 which has irradiated laser will be in the state where ionized and it had a charge. For this reason, the particle 32 which can catch a particle (trap), can be moved to a desired position by applying electric field to the condensing part of laser, and adheres to the samples 31 and 41 which are workpieces is arranged like expected.
[0021] Moreover, when using the operation effect of electric field instead of laser, electric field are applied to the electrode for traps, a particle 32 can be made to be able to polarize, it can be made to be able to move to the position of a request of the particle 32 by which the trap was carried out, and a regular array can be attained. Furthermore, when using the operation effect of a magnetic field, the particle 32 which consists of the magnetic substance, such as a ferrite, can be distributed in a solution, a magnetic field can be applied with an electromagnet, a permanent magnet, etc. from the exterior, and a particle 32 can be made to arrange regularly in accordance with magnetic flux. In addition, when positioning a particle 32 per nano, it is possible to attach an electrode and a magnetic pole in a piezo-electric element, to expand or shrink a piezo-electric element per nano by carrying out adjustable [of the voltage impressed to a piezo-electric element], to control the variation rate of the electrode accompanying it or a magnetic pole, and to position a particle 32 with a sufficient precision.
[0022] The workpiece 50 shown in drawing 5 shows the example of processing at the time of carrying out energy beam processing by the arrangement pattern which arranged two or more columnar structure objects 54 in the single tier, respectively on the 2 sides 51a and 51b in which a sample 51 crosss diagonally mutually. The diameter of a cross section of each columnar structure object 54 is 1nm - 20nm, and the height is 10nm - 500nm. The optical-axis line which puts each train of the columnar structure 54 of these 2 train in a row crosses at Point P, and carries out the amplifier of the quantum effect in response to the laser from the device 55 which carries out outgoing radiation of the laser, respectively. Or a resonator mirror is prepared in the both sides of the cylindrical structure, and outgoing radiation of the laser beam accompanied by the quantum effect by which outgoing radiation is carried out from there is carried out. In this case, in order for the columnar structure object 55 of two trains to carry out the short wavelength shift of the laser or to carry out a high intensity oscillation, the optical place of high intensity is formed in the point P which the laser of two trains concentrates. In addition, the technology which forms the optical place of high intensity using the detailed columnar-structure object 54 of such plurality irradiates the atom on the front face of the matter, and can make laser it to be not only applicable to trap operation of the particle by the above-mentioned laser, but able to emit light, can fly an atom, can make it able to ionize it, or it can apply to the surface atom photoreaction, such as cutting off the chain between atoms, etc., and paves the path for a broad applied technology.
[0023] The workpiece 60 shown in drawing 6 is formed in Si substrate which steps on the process of Si which overly showed the detailed cone structure 64 to the 2nd example of the above, and constitutes a sample 61. In this example, the high-speed atomic line using the gas particle of fluorine systems, such as SF6, as an energy beam is used in consideration of using Si substrate as a sample 61. It carries out from supplying the fluorine radical which made the plasma of a fluorine system gas particle and was

made there in large quantities to the sample front face after high-speed atomic-line irradiation also about isotropic processing. thus, AFM (atomic force microscope) for the cone structure 64 of made Si observing the surface state of the matter -- or it can use as a needle at the nose of cam of a cantilever of STM (tunneling microscope) The needle at the nose of cam of a cantilever is used for the probe of the irregularity of the front face for observation, and can observe the shape of surface type from the vertical movement of a needle which imitated surface irregularity. Moreover, since the cone structure 64 is acute structure, electric-field concentration is easy for it, and it can be used also as an electron source for field emission which outputs an electron ray from a needle for this reason. The application to the electron beam exposure system which surrounds with an insulator the needlelike micro emitter manufactured as the cone structure with detailed field emission, is controlling the potential of the beam drawer electrode prepared in insulator opening, is made to emit an electron ray from the nose of cam of a micro emitter, and is used for electron beam nano lithography technology etc. is possible.

[0024] Drawing 7 shows the example of manufacture of the hyperfine-structure element 70 which gave 3-dimensional multiple processing which applied the energy beam processing method of this invention. Upper surface 71a of the sample 71 of a cube configuration, the cone structure 74 which has the fine structure processed into side 71b by the above-mentioned processing method, respectively, and the pillar structure 75 exist, and a different quantum effect that each is a grade is demonstrated. If optical amplification of the laser L2 is carried out between mirror 75a and outgoing radiation mirror 75b which carried out optical amplification of the laser L1 between mirror 74a and outgoing radiation mirror 74b which carried out opposite arrangement on both sides of the cone structure 74, and carried out opposite arrangement on both sides of the pillar structure 75 on the other hand, both the laser L1 and L2 will be oscillated on different wavelength according to the difference in the quantum effect based on the configuration of the cone structure 74 and the pillar structure 75.

[0025] Both are led to transverse-plane 71c of a sample 71, respectively, after the laser L1 by which an oscillation output is carried out through outgoing radiation mirror 74b, and the laser L2 by which an oscillation output is carried out through outgoing radiation mirror 75b are crooked right-angled in an optical path with reflecting mirrors 76 and 77, although wavelength differed. The laser led to transverse-plane 71c of a sample 71 is chosen or compounded by the rotation mirror 78, and is detected by the appropriate after light sensitive cell 79. The front rear face consists of optical mirrors which have wavelength-selection nature, respectively, according to the rotation phase of the rotation mirror 78, both can penetrate a rotating mirror 78 and, as for laser L1 and L2, only one side can realize the wavelength-selection element which can perform selection and mixing of two kinds of wavelength by this so that selection and composition of two kinds of wavelength can do the rotation mirror 78.

[0026] Moreover, in order to use the hyperfine-structure element 70 as a source of data generation for for example, information communication, when two data streams from which wavelength differs are transmitted through the same bus line or a separate bus line, it will end with one half of transmission times compared with the case where the 16-bit amount of data is transmitted using single wavelength. This is based on a bird clapper as it is possible to transmit simultaneously the pulse data with which wavelength differs using bus lines, such as the same optical fiber. In this case, the light sensitive cell 79 builds in the wavelength-selection element which induces wavelength lambda1 and lambda2, from each wavelength-selection element, received data are outputted through the eight data lines connected to the preamplifier and the parallel signal generation machine, respectively, and 8-bit data are transmitted towards a memory device or a related equipment, respectively. That is, since the data for two waves can be processed at once, the 2x8=16 bit amount of data becomes possible in one half of time. If a wavelength kind is increased similarly, the increase in the amount of data of an integral multiple bit will become possible in same time. In this case, since the data from which wavelength differs by the hyperfine-structure element 70 are transmitted simultaneously, at once, a lot of communication of information is possible, and this can realize as a communication-of-information element of high capacity very much.

[0027] In addition, it can replace with the rotation mirror 78 and a polarizing element controllable on a one-way mirror or an electric target etc. can also be used. Moreover, a light sensitive cell 79 can also be constituted using two independent photo detectors corresponding to each wavelength lambda1 and lambda2, and although it produces the need of arranging the phase of transmission data in that case, it becomes unnecessary [the mirror which distributes outgoing radiation light]. Furthermore, two or more data streams from which wavelength differs can be simultaneously transmitted by forming the two or more cylindrical structures in the hyperfine-structure element 70.

[0028] In addition, as an energy beam applicable to the energy beam processing method of the above-mentioned this invention, although the high-speed atomic line, an ion beam, an electron ray, laser, synchrotron orbital radiation, an atom, a molecular beam, etc. are mentioned, each feature is as follows. The high-speed atomic line which is a high-speed, neutral energy corpuscular ray can be applied to all material, such as a metal, and a semiconductor or an insulator, and the ion beam is very effective to a metallic material. Only the place where the electron ray was irradiated can make a chemical reaction produce electron ray] by introducing the gas which has reactivity to a sample simultaneously with irradiation. Moreover, synchrotron orbital radiation enables colorful processing by irradiating and processing only direct synchrotron orbital radiation into a sample front face, or processing it using an interaction with a reactant gas particle. Moreover, an atom and a molecule beam enable beam processing of low energy by irradiating the atom and molecule beam of a reactant gas particle. For this reason, it is good to use various energy beams according to the processing purpose.

[0029]

[Effect of the Invention] As explained above, according to this invention, the diameter which covers an energy beam on the surface of a workpiece distributes a particle (0.1nm, 10nm, 10nm, 100nm, 100nm, or 10 micrometers). The shell which irradiates an energy beam at the aforementioned workpiece and processed the aforementioned workpiece front face except the covered part by the aforementioned particle, Micro processing in the size order of a particle or size order minuter than a particle is possible. A

sake therefore, manufacture of the difficult overly detailed processing structure is possible, and a particle is made to adhere on the surface of a workpiece with the conventional photolithography technology -- being sufficient -- Since it can arrange easily not related to the granularity and flatness on the front face of a workpiece, therefore ultraviolet radiation cannot irradiate ** - to a sample with crude surface flatness or surface granularity, by ** -, accurate resist film attachment is difficult, or Or it differs from the conventional photolithography technology applied only to the whole surface with sufficient flatness even if it made it the processing side. With combination with anisotropy processing by energy beam processing which an ultrafine particle is distributed for the part and many sides of a sample, and the micro-machining of the three-dimensional structure is possible for, and was excellent in especially directivity overly in a detailed field By being able to raise a process tolerance, and making laser, a magnetic field or electric field, etc. act, arranging a particle regularly and processing it The effect which was [offer / the industrial very / scientifically or / meaningful processing method / becoming realizable / the micro quantum effect element or a micro memory device, or a light-corpuscle child / etc.] excellent is done so.

[0030] Moreover, by irradiation of an energy beam, while this invention processes a workpiece front face in the depth direction, it carries out diameter reduction processing of the aforementioned particle gradually. To the shell which processed the cylindrical structure of a taper into the covered part of this particle, and the reactant gas particle used, for example as an energy beam, reactivity is low and a sputtering yield by using a low particle Because reactivity uses a high particle also with a high sputtering yield to the reactant gas particle which suppresses configuration change of the particle under processing, processes a workpiece into the cylindrical structure with the wall near a perpendicular wall, or uses it as an energy beam Configuration change of the particle can be greatly carried out during processing, a workpiece can be processed into the cylindrical structure of tapers, such as the shape of a cone, and a pyramid configuration, and the effect that the configuration of the structure which carries out remains formation on the surface of a workpiece is processible into the configuration of an optional request etc. is done so.

[0031] this invention to the workpiece which irradiated the energy beam and performed micro processing further again Introduce the gas particle which shows chemical reactivity to this workpiece, and the chemical reactivity on this front face of a workpiece is controlled by the temperature control. In the shell which processed this workpiece front face isotropic, and the sample which gave energy beam processing By introducing particles, such as a sample, reactant high gas, for example, chlorine gas, and fluorine gas, and heating a sample by the heater or the heat lamp By being able to give legal processing, such as not having directivity, and giving this ** legal processing When reduction processing is carried out by the constant ratio and not only a remains particle but the cylindrical structure is compared with processing only by the high-speed atomic line, the effect of being able to make the cylindrical structure which has a still more detailed cross-section configuration is done so.

[0032] Furthermore, as an energy beam, since the high-speed atomic line, an ion beam, an electron ray, laser, synchrotron orbital radiation, or an atom and a molecular beam was used for this invention When the atomic line which is an energy corpuscular ray of high-speed neutrality as an energy beam is used Are applicable to all material, such as a metal, and a semiconductor or an insulator. as an energy beam for example, when an ion beam is used When it is very effective and an electron ray is further used as an energy beam to a metallic material By introducing the gas which has reactivity to a sample simultaneously with electron beam irradiation When only the place where the electron ray was irradiated can make a chemical reaction produce and synchrotron orbital radiation is used as an energy beam By irradiating and processing only direct synchrotron orbital radiation into a sample front face, or processing it using an interaction with a reactant gas particle colorful processing is possible, and when an atom and a molecule beam are used as an energy beam, the atom and molecule beam of a reactant gas particle are irradiated, and beam processing of low energy is possible -- etc. -- effect is taken

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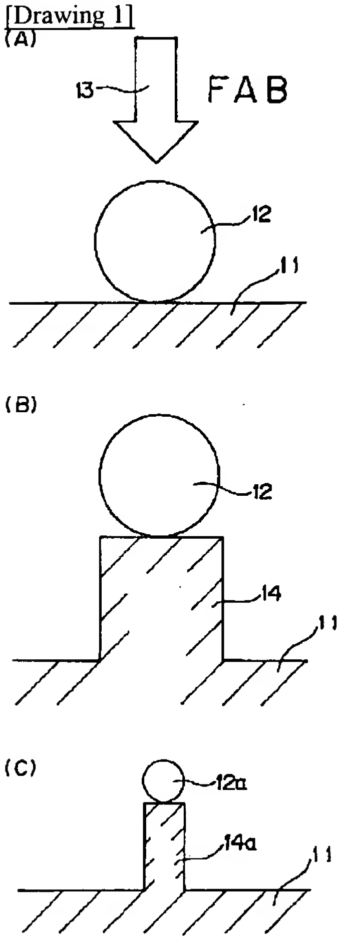
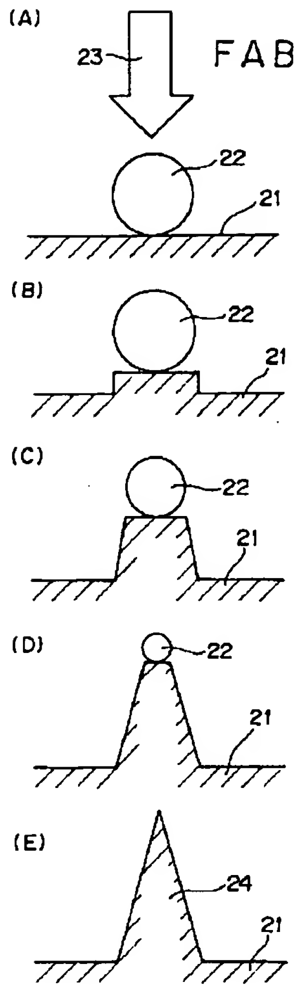
[Translation done.]

DRAWINGS

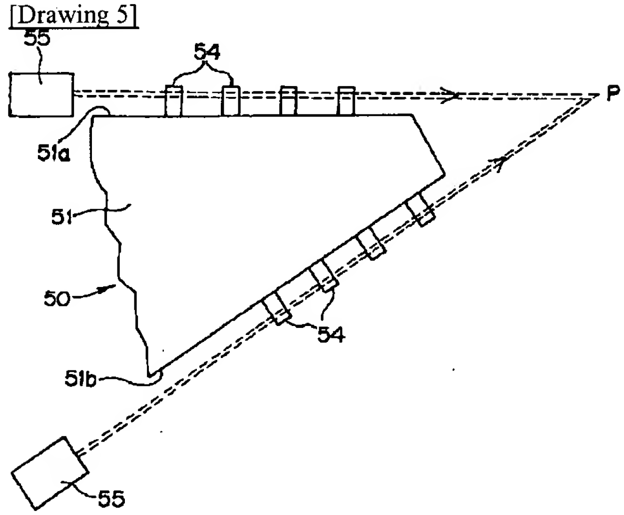
[Drawing 1]



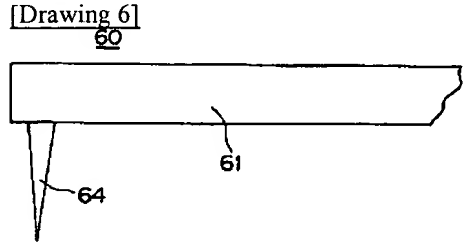
[Drawing 2]



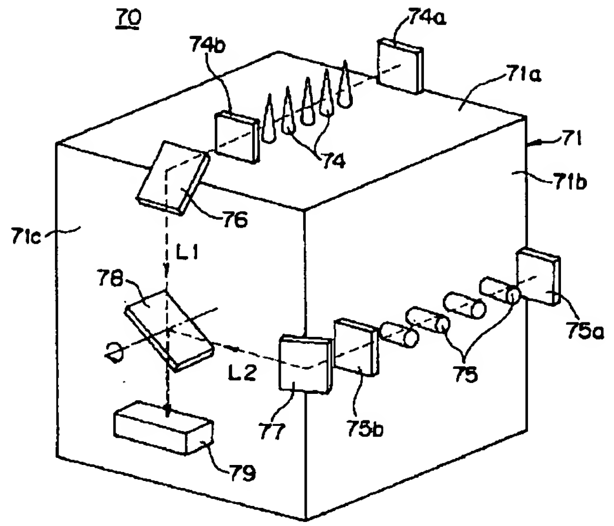
[Drawing 5]



[Drawing 6]



[Drawing 7]



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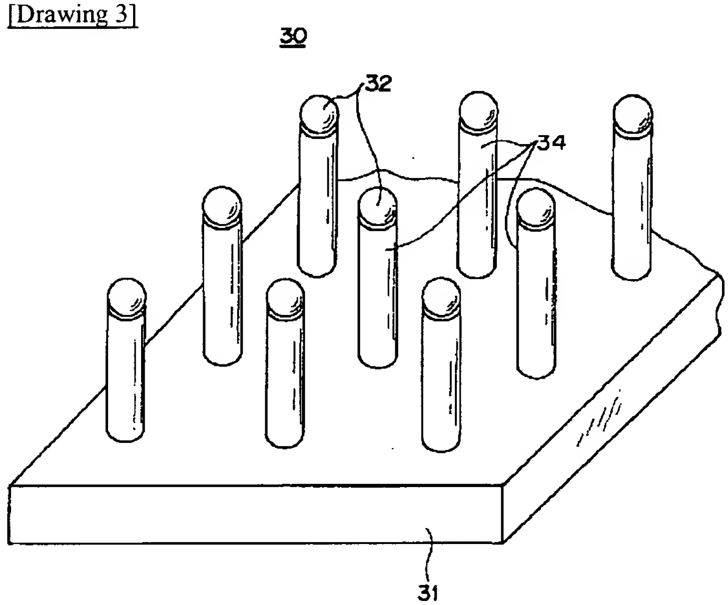
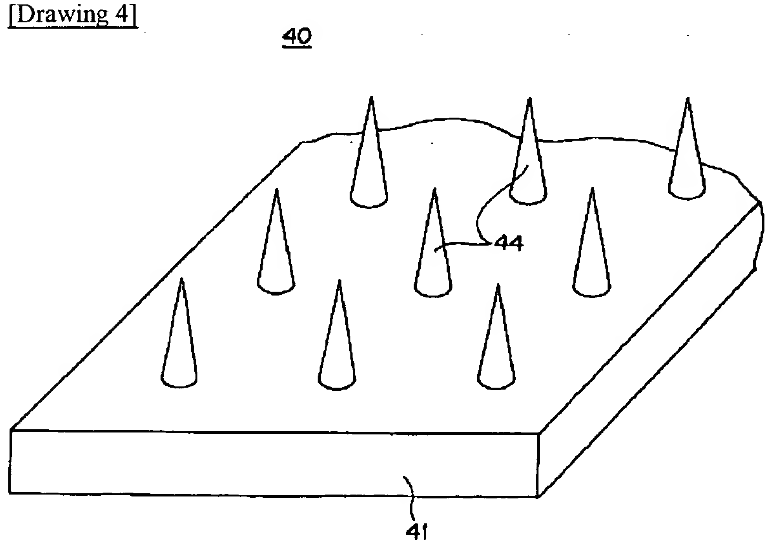
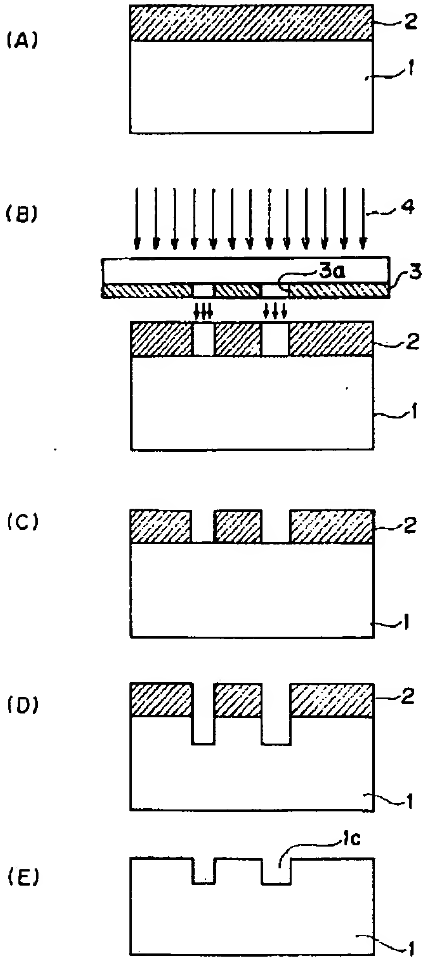


[Drawing 4]



[Drawing 8]



[Translation done.]

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26/00                   .
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C23F     4/02               .
G02F     1/35      503        .
H01S     3/00               .
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[FI]

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B01J    19/08          Z      .
B23K    17/00               .
26/00         E         .
B26F     3/00          Z      .
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G02F     1/35      503        .
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[Procedure revision]
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[Procedure amendment 1]
[Document to be Amended] Specification.
[Item(s) to be Amended] Claim.
[Method of Amendment] Change.
[Proposed Amendment]
[Claim(s)]
[Claim 1] The energy beam processing method characterized by for the diameter which covers an energy beam on the surface of a workpiece distributing a particle (0.1nm, 10nm, 10nm, 100nm, 100nm, or 10 micrometers), irradiating an energy beam at the aforementioned workpiece, and processing the aforementioned workpiece front face except the covered part by the aforementioned particle.
[Claim 2] The energy beam processing method according to claim 1 which carries out diameter reduction processing of the aforementioned particle gradually by irradiation of the aforementioned energy beam while processing this workpiece front face in the depth direction, and is characterized by processing the cylindrical structure of a taper into the covered part of this particle.
[Claim 3] The claim 1 characterized by making homogeneity distribute the aforementioned particle mostly with a surface active agent in solvents, such as ethanol, making a solution, dropping this solution at a workpiece front face, or dipping a workpiece into this solution, distributing the aforementioned particle uniformly on a workpiece front face, and irradiating an energy beam at this workpiece, or the energy beam processing method of two given in any 1 term.
[Claim 4] The claim 1 characterized by making a magnetic field, electric field, or laser act on the particle on the aforementioned front face of a workpiece, and carrying out the configuration control of this particle according to a processing pattern, or the

energy beam processing method of three given in any 1 term.
[Claim 5] The claim 1 characterized by introducing the gas particle which shows chemical reactivity to this workpiece into the workpiece which irradiated the energy beam and performed micro processing, controlling the chemical reactivity on this front face of a workpiece to it by the temperature control, and processing this workpiece front face into it isotropic, or the energy beam processing method of four given in any 1 term.
[Claim 6] The claim 1 to which the aforementioned energy beam is characterized by being the high-speed atomic line, an ion beam, an electron ray, laser, synchrotron orbital radiation, or an atom and a molecular beam, or the energy beam processing method of four given in any 1 term.

[Translation done.]

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B23K　17/00			B23K	17/00	
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B26F　3/00			B26F	3/00	Z
C23F　4/02			C23F	4/02	

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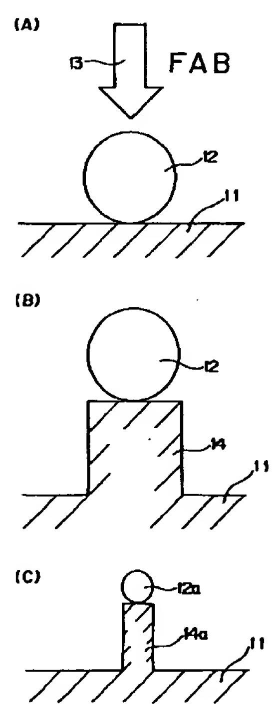
(54)【発明の名称】　エネルギービーム加工法

(57)【要約】
【目的】　被加工物表面に微粒子を分散配置してエネルギービームを照射し、微粒子の寸法オーダーで微細加工を施す。
【構成】　被加工物である試料11の表面にエネルギービームを遮蔽するほぼナノメータスケールの微粒子12を分散配置し、試料11にエネルギービームを照射し、微粒子12が配置された箇所を除く試料表面を加工することにより、従来のフォトリソグラフィ技術では実現困難な微細加工が可能となる。必要に応じて磁界や電界或いはレーザ等を作用させて微粒子12を配置制御し、さらにエネルギービーム照射により得られた棒状構造物14に、化学反応性ガス粒子や溶液中にて等方的加工を施し、より微細でアスペクト比の高い棒状構造物14aを製作することができる。



1

【特許請求の範囲】

【請求項１】　被加工物の表面にエネルギービームを遮蔽する直径が０．１nmないし１０nmもしくは１０nmないし１００nmもしくは１００nmないし１０μmの微粒子を分散配置し、前記被加工物にエネルギービームを照射し、前記微粒子による遮蔽箇所を除く前記被加工物表面を加工することを特徴とするエネルギービーム加工法。

【請求項２】　前記エネルギービームの照射により、該被加工物表面を深さ方向に加工する一方で前記微粒子を徐々に縮径加工し、該微粒子の遮蔽箇所に先細の棒状構造物を加工することを特徴とする請求項１記載のエネルギービーム加工法。

【請求項３】　前記微粒子をエタノール等の溶剤中に表面活性剤と共にほぼ均一に分散させて溶液を作り、該溶液を被加工物表面に滴下するか又は該溶液中に被加工物を浸して前記微粒子を被加工物表面に均一に分散配置し、該被加工物にエネルギービームを照射することを特徴とする請求項１又は２のいずれか１項記載のエネルギービーム加工法。

【請求項４】　前記微粒子が、フェライト、コバルト、亜鉛、ダイヤモンドの超微粒子であることを特徴とする請求項１ないし３のいずか１項記載のエネルギービーム加工方法。

【請求項５】　前記被加工物表面の微粒子に磁界又は電界又はレーザ等を作用させ、該微粒子を加工パターンに合わせて配置制御することを特徴とする請求項１ないし４のいずか１項記載のエネルギービーム加工法。

【請求項６】　前記被加工物が、ＧａＡｓ，ＩｎＡｓ，ＡｌＧａＡｓ，ＩｎＧａＡｓ等のIII－V属系の半導体材料であることを特徴とする請求項１ないし５のいずれか１項記載のエネルギービーム加工法。

【請求項７】　前記被加工物がＳｉ，ＳｉO$_2$などのＳｉ含有半導体材料であることを特徴とする請求項１ないし５のいずれか１項記載のエネルギービーム加工法。

【請求項８】　加工された被加工物が量子効果を発生することを特徴とする請求項１ないし７項のいずれか１項記載のエネルギービーム加工法。

【請求項９】　エネルギービームを照射して微細加工を施した被加工物に、該被加工物に対し化学反応性を示すガス粒子を導入し、温度制御により該被加工物表面の化学反応性を制御し、該被加工物表面を等方的に加工することを特徴とする請求項１ないし８のいずれか１項記載のエネルギービーム加工法。

【請求項１０】　前記エネルギービームが、高速原子線又はイオンビーム又は電子線又はレーザ又は放射光又は原子・分子線であることを特徴とする請求項１ないし８のいずれか１項記載のエネルギービーム加工法。

【発明の詳細な説明】

【０００１】

2

【産業上の利用分野】本発明は、被加工物表面に微粒子を分散配置してエネルギービームを照射し、微粒子の寸法オーダー、もしくは微粒子の寸法より微小寸法オーダーで微細加工を施すようにしたエネルギービーム加工法に関する。

【０００２】

【従来の技術】半導体プロセスにおける基板加工には、基板の加工パターンに合わせた形状のフォトレジストマスクを用いるフォトリソグラフィ技術が重要な役割を果たしてきた。フォトリソグラフィ技術による基板加工では、基板上の加工しない部分をフォトレジストマスクで覆い、フォトレジストマスクで覆われていない部分にエッチング加工を施し、加工時間に応じた深さに加工する。

【０００３】図8は、フォトレジストマスクを用いる従来の微細加工法の工程例を示すものであり、同図（Ａ）～（Ｅ）が第１～第５の各工程を示す。まず第１工程において、加工基板１にレジスト材２をコーティングする。次に、第２工程において、フォトマスク３を介在させて加工基板１表面のレジスト材２に紫外線４を照射し、フォトマスク３に形成されたパターン穴３ａをレジスト材２に転写する。次に、第３工程において、現像によりパターン穴３ａを介して紫外線４が照射された部分のレジスト材２を除去し、必要なフォトレジスト膜のみを残す。続く第４工程では、プラズマ中のイオンやラジカル種を利用し、加工基板１上のレジスト材２が無い部分に異方性エッチングを施し、最後の第５工程において、レジスト材２を除去する。以上、第１～第５工程を経て加工板１の表面にフォトマスク３のパターン穴３ａと同形の穴１ｃを形成する微細加工が行われる。なお、一般の半導体デバイスでは、上記第１～第５行程を繰り返し行うことで、加工基板１上に深さの異なる穴を複数形成するのが普通である。

【０００４】

【発明が解決しようとする課題】上記従来のフォトリソグラフィ技術を用いた微細加工法は、製作過程の煩雑なフォトレジストパターーンを有するフォトマスク３が不可欠であり、しかもこのフォトレジストパターンを１μm以下の線幅或いは径に加工するには、特別な装置や工夫を必要とする上、時間的にもコスト的にも相当の損失を覚悟しなければならず、ナノメータスケールの微細加工に簡単に適用できるものではなかった。また、レジスト材２は、紫外光や電子線に感光することが必須条件であるため、おのずと使用可能な材料が制限されてしまい、またレジスト材２がコンタミ成分となるときには、使用できないといった制限があった。さらに、フォトレジスト膜作製に関しても、表面の平坦度や粗さが粗悪な試料に対しては紫外光を均一に照射できないため、均一で精度の良いレジスト膜付けは困難であった。

【０００５】また、従来のプラズマプロセスを用いて１

μm以下のパターン構造の加工を行うにしても、ガス粒子の衝突やレジスト材のチャージアップ等の影響で、斜め入射するエネルギー粒子の粒子数が多く、このため垂直で背の高い微細構造体の加工、すなわちアスペクト比（加工深さに対する構造体幅の比）の高い加工は困難であり、構造体の幅が１μm以下の加工は殆ど無理であった。

【０００６】従って、本発明の目的は、被加工物表面に微粒子を分散配置し、エネルギービームを照射して加工を行うことにより、ナノメータスケールの微細加工を可能にすることにあり、必要に応じて磁界や電界或いはレーザ等を作用させて微粒子を配置制御し、さらにエネルギービームを照射した後で化学反応性ガス粒子や溶液中にて等方的加工を施し、より微細でアスペクト比の高い構造物を製作することにある。

【０００７】

【課題を解決するための手段】本発明は、被加工物の表面にエネルギービームを遮蔽する直径が０．１nmないし１０nmもしくは１０nmないし１００nmもしくは１００nmないし１０μmの微粒子を分散配置し、前記被加工物にエネルギービームを照射し、前記微粒子による遮蔽箇所を除く前記被加工物表面を加工することを特徴とするエネルギービーム加工法を提供することにより、前記目的を達成するものである。

【０００８】また、本発明は、前記エネルギービームの照射により、該被加工物表面を深さ方向に加工する一方で前記微粒子を徐々に縮径加工し、該微粒子の遮蔽箇所に先細の棒状構造物を加工すること、或いは前記微粒子をエタノール等の溶剤中に表面活性剤と共にほぼ均一に分散させて溶液を作り、該溶液を被加工物表面に滴下するか又は該溶液中に被加工物を浸して前記微粒子を被加工物表面に均一に分散配置し、該被加工物にエネルギービームを照射すること等を特徴とするエネルギービーム加工法を提供することにより、前記目的を達成するものである。

【０００９】さらに、本発明は、前記被加工物表面の微粒子に磁界又は電界又はレーザ等を作用させ、該微粒子を加工パターンに合わせて配置制御すること、或いはエネルギービームを照射して微細加工を施した被加工物に、該被加工物に対し化学反応性を示すガス粒子を導入し、温度制御により該被加工物表面の化学反応性を制御し、該被加工物表面を等方的に加工すること等を特徴とするエネルギービーム加工法を提供することにより、前記目的を達成するものである。

【００１０】

【作用】本発明によれば、被加工物の表面にエネルギービームを遮蔽するほぼナノメータスケールの微粒子を分散配置し、前記被加工物にエネルギービームを照射し、前記微粒子による遮蔽箇所を除く前記被加工物表面を加工することにより、従来のフォトリソグラフィ技術では実現困難な微細加工が可能となる。

【００１１】

【実施例】以下、本発明の実施例について、図１ないし図７を参照して説明する。図１は、本発明のエネルギービーム加工法の一実施例を示す工程図である。

【００１２】図１（Ａ）に示すように、加工対象であるＧａＡｓ，Ｓｉ，ガラスなどの試料１１の表面に、直径５nm～１μm程度のコバルトや、Ｚｎ（亜鉛）や、フェライトの微粒子１２を分散配置する。この分散配置は付着によりなされ、具体的には、エタノール等の溶剤中に表面活性剤と共に微粒子１２を混入し、攪拌して均一な濃度分布となった溶液中に試料１１を浸すか、或いは溶液を試料１１の表面に滴下して乾燥させることで、試料１１の表面に微粒子１２を均一に付着させることができる。こうして、エネルギービームを遮蔽する微粒子１２が確率的な精度をもって試料１１の表面に均一に分散配置される。

【００１３】次に、エネルギービームである高速原子線１３を、図１（Ａ）に矢印で示した方向に沿って、試料１１にほぼ垂直に照射する。このとき、微粒子１２で覆われた箇所は高速原子線１３を遮蔽するため、微粒子１２で覆われていない箇所だけが高速原子線１３によって加工され、図１（Ｂ）に示した加工が進行する。

【００１４】ただし、高速原子線１３による加工は試料１１だけでなく微粒子１２にも及ぶため、厳密には微粒子１２は照射の進行とともに徐々に縮径加工される。しかしながら、この微粒子１２の形状変化は、高速原子線１３に用いるガスとの反応性によって異なる。そこで、高アスペクト比の加工を実現するため、ここでは希ガスもしくは、微粒子１２には反応性が低く、試料とは反応性の高いガスからなる高速原子線１３を用い、微粒子１２の形状変化をできる限り抑制する加工法を採用する。その結果、微粒子１２が付着した箇所だけを棒状の垂直な壁として未加工のまま残すことができる。こうして試料１１の表面に残された棒状構造物１４は、微粒子１２の寸法に従って５nm～１μmの断面径を有する棒状の微細構造をなし、粒径が均一な微粒子１２を用いるほど形状の均一化が徹底される。

【００１５】なお、上記のエネルギービーム加工を施した試料１１に、試料１１と反応性の高いガス例えば塩素ガスやフッ素ガス等の粒子を導入し、試料１１をヒータ或いは加熱ランプにより加熱することにより、図１（Ｃ）に示したように、方向性をもたない等法的加工を施すことができる。この等法的加工を施すことで、残留微粒子１２だけでなく棒状構造物１４も一定比で縮小加工され、高速原子線１３のみによる加工と比較したときに、より微細な断面形状を有する棒状構造物１４ａに仕上げることができる。また、最終的に残った微粒子１２ａは、多くの場合不要であるため、例えば超純水ウォータージェット洗浄等により棒状構造物１４ａの頂部から

除去するとよい。

【0016】ところで、上記エネルギービーム加工に用いる試料11としては、半導体材料のＧａＡｓ、Ｓｉ，SiO_2などの基板、或いは絶縁物のガラスやセラミック、さらには金属材料など、あらゆる材料を用いることができる。また、微粒子12は、０．１μm以下の超微粒子が必要な場合は、フェライト，亜鉛，コバルト，ダイヤモンド等の超微粒子を用いるとよく、また０．１～１０μｍの粒径が要求される場合は、アルミナ，グラファイト，金微粒子，銀微粒子等の微粒子１２を用いるとよい。さらに、これらの微粒子１２を材質面で選択するときは、反応性ガス粒子との反応性やスパッタ特性等を考慮して適当な材質のものを用いるとよい。

【0017】なお、上記実施例では、エネルギービームとして希ガスもしくは、基板とは反応性が高く微粒子とは反応性が低いガスの高速原子線１３を用い、エネルギービームと微粒子１２との反応性を抑制するようにしたが、これとは若干異なる実施例として、図２（Ａ）～（Ｅ）に加工工程を示したエネルギービーム加工法も有意義である。この加工法は、エネルギービームによる微粒子自体の形状変化をある程度見込むものであり、ここでは試料２１として、ＧａＡｓ，ＡｌＧａＡｓ，ＩｎＡｓなどのIII－V属系の半導体材料を用い、さらに高速原子線２３として、塩素ガスの高速原子線を用いるとともに、微粒子２２として、塩素ガスの高速原子線２３に反応性を示す粒径１ｎｍ～５０ｎｍのダイヤモンド超微粒子を用いる。

【0018】まず、図２（Ａ）に示したように、試料２１の表面にダイヤモンド超微粒子２２を分散配置し、矢印の方向に塩素ガスの高速原子線２３を照射する。これにより、図２（Ｂ），（Ｃ）に示したように、試料２１表面の加工が進行するが、同時にまたそれよりも遅い加工速度ながらダイヤモンド微粒子２２も徐々に加工される。ダイヤモンド微粒子２２の粒径が縮径されるのに伴い、高速原子線２３に対するダイヤモンド微粒子２２の遮蔽面積も縮小していくため、ダイヤモンド微粒子２２によって遮蔽された部分の試料２１は、図２（Ｄ）に示したように先細の棒状構造物２４に加工されていく。実施例では、ダイヤモンド微粒子２２が消失するまでビーム照射を継続するようにしているため、最終的には図２（Ｅ）に示したように、尖塔すなわち先端の尖った先細の棒状構造物２４が実現される。ちなみに、この加工法により実際に製作された棒状構造物２４は、先端の径が１０ｎｍと微細であるにも拘わらず、高さが２５０ｎｍ程度と十分なアスペクト比を備えるものであった。

【0019】なお、エネルギービーム加工後に棒状構造物２４の先端をさらに先鋭化するため、前記実施例と同様、ビーム照射後に塩素ガスのみを導入し、試料２１をヒータや加熱用ランプで加熱することにより、等方的加工を施すことも可能である。その場合には、棒状構造物２４は、さらに先細の０．１ｎｍ～５ｎｍの先端径に加工される。また、このように、高速原子線を照射した後で、加熱による化学反応表面加工を行った場合には、表面のスムージングやダメージ層の除去に効果があり、量子効果素子を製作するときなどに特に有効である。量子効果とは、微小構造物がもつバルク特性とは異なる特性、例えば光の波長を短波長側にシフトさせたり、電子エネルギの準位を変化させたりする特性を示す効果を指し、例えば、棒状構造物から放射される光やレーザー光が、バルクとは異なる短波長側にシフトとた波長を示したり、棒状構造物にレーザ光を通過させたときに、量子効果によりレーザ光が短波長側にシフトすることで、レーザ光の強度を増幅することが可能である。

【0020】図３，４に示した被加工物３０，４０は、微粒子を二次元平面に規則的に配列してエネルギービーム加工を行った場合の加工例を示すものである。すなわち、図３に示した被加工物３０は、試料３１の表面に棒状構造物として列柱３４を所定の配置パターン（マトリクス配置パターン）に従って配列したものであり、図４に示した被加工物４０は、試料４１の表面に棒状構造物として円錐４４を所定のマトリクス配置パターンで配列したものである。この場合の加工法は、基本的には前述のビーム照射を踏襲するものであるが、微粒子３２の配置制御にレーザや電界や磁界の作用を用い、棒状構造物（列柱３４や円錐４４）を確率的な分布配列から規則的な分布配列に強制する点で、より高度な加工法であると言える。レーザは、照射された微粒子３２自体を電離させるか、或いは微粒子３２の周囲を電離させてプラズマを形成するため、レーザを照射された微粒子３２は電離して電荷をもった状態となる。このため、レーザの集光箇所に電界をかけることで、微粒子を捕捉（トラップ）して所望の位置へと移動させることができ、被加工物である試料３１，４１に付着する微粒子３２は、所期のごとく配置される。

【0021】また、レーザの代わりに電界の作用効果を利用する場合は、トラップ用電極に電界をかけて微粒子３２を分極化させ、トラップされた微粒子３２を所望の位置へと移動させて規則的配列を達成することができる。さらに、磁界の作用効果を利用する場合は、フェライトなど磁性体からなる微粒子３２を溶液中に分散させ、外部から電磁石や永久磁石等により磁界をかけ、磁束に沿って微粒子３２を規則的に配列させることができる。なお、微粒子３２をナノ単位で位置決めする場合は、例えばピエゾ素子に電極や磁極を取り付け、ピエゾ素子に印加する電圧を可変することによりピエゾ素子をナノ単位で膨張又は収縮させ、それに伴う電極や磁極の変位を制御し、微粒子３２を精度よく位置決めすることが可能である。

【0022】図５に示す被加工物５０は、試料５１の互いに斜交する二側面５１ａ，５１ｂに、複数の柱状構造

物５４をそれぞれ一列に並べた配置パターンでエネルギービーム加工した場合の加工例を示すものである。各柱状構造物５４の断面径は、１ｎｍ～２０ｎｍであり、その高さは１０ｎｍ～５００ｎｍである。これら２列の柱状構造５４の各列を連ねる光軸線は点Ｐで交差しており、それぞれレーザを出射する機器５５からのレーザを受けて量子効果をアンプする。もしくは、棒状構造物の両側に共振器ミラーを設けて、そこから出射される量子効果を伴ったレーザー光を出射する。この場合、２列の柱状構造物５５がレーザを短波長シフトさせたり或いは高強度発振させたりするため、２列のレーザが集中する点Ｐには高強度の光場が形成される。なお、こうした複数の微細な柱状構造物５４を利用して高強度の光場を形成する技術は、前述のレーザによる微粒子のトラップ操作に応用できるだけでなく、レーザを物質表面の原子に照射して発光させたり、原子を飛ばしたり電離させたり原子間の鎖を断ち切るなどの表面原子光反応等にも応用でき、幅広い応用技術に道を開くものである。

【００２３】図６に示す被加工物６０は、Ｓｉの超微細円錐構造物６４を前記第２実施例に示した工程を踏んで試料６１を構成するＳｉ基板に形成したものである。この実施例では、試料６１としてＳｉ基板を用いることを考慮し、エネルギービームとしてはSF_6などのフツ素系のガス粒子を用いた高速原子線を使用する。等方的加工に関しても、フッ素系ガス粒子のプラズマを作り、そこで作られたフッ素ラジカルを高速原子線照射後の試料表面に大量に供給することより行う。このようにして出来たＳｉの円錐構造物６４は、物質の表面状態を観察するためのＡＦＭ（原子間力顕微鏡）や、或いはＳＴＭ（トンネル顕微鏡）のカンチレバー先端の針として用いることができる。カンチレバー先端の針は、観察対象表面の凹凸の探針に用いられ、表面の凹凸に倣った針の上下動から表面形状を観測することができる。また、円錐構造物６４は先鋭構造であるため、電界集中が容易であり、このため針から電子線を出力するフィールドエミッション用電子源としても利用することができる。フィールドエミッションとは、微細な円錐構造物として製作した針状のマイクロエミッタをインシュレータで囲繞し、インシュレータ開口部に設けたビーム引き出し電極の電位を制御することで、マイクロエミッタの先端から電子線を放射させるものであり、電子ビームナノリソグラフィ技術等に用いる電子ビーム描画装置等への応用が可能である。

【００２４】図７は、本発明のエネルギービーム加工法を適用した３次元の多面加工を施した超微細構造素子７０の製作例を示すものである。立方体形状の試料７１の上面７１ａと側面７１ｂにはそれぞれ、前述の加工法により加工された微細構造を有する円錐構造物７４と円柱構造物７５とが存在し、それぞれが程度の異なる量子効果を発揮する。円錐構造物７４を挟んで対向配置したミラー７４ａと出射ミラー７４ｂとの間でレーザＬ１を光増幅し、他方で円柱構造物７５を挟んで対向配置したミラー７５ａと出射ミラー７５ｂとの間でレーザＬ２を光増幅すると、両レーザＬ１，Ｌ２は円錐構造物７４と円柱構造物７５の形状に基づく量子効果の違いに応じて異なる波長で発振する。

【００２５】出射ミラー７４ｂを介して発振出力されるレーザＬ１と出射ミラー７５ｂを介して発振出力されるレーザＬ２は波長が異なるが、両者はそれぞれ反射鏡７６，７７で光路を直角に屈曲されたのち、試料７１の正面７１ｃに導かれる。試料７１の正面７１ｃに導かれたレーザは、回転ミラー７８にて選択或いは合成され、しかるのち光検出器７９によって検出される。回転ミラー７８は、２種類の波長の選択と合成ができるよう、表裏面がそれぞれ波長選択性のある光学ミラーで構成されており、レーザＬ１，Ｌ２は、回転ミラー７８の回転位相に応じて一方だけ或いは両方が回転鏡７８を透過することができ、これによって２種類の波長の選択やミキシングができる波長選択素子を実現することができる。

【００２６】また、超微細構造素子７０を例えば情報通信用のデータ生成源として利用するため、波長の異なる２つのデータ列を同一のバスライン又は別個のバスラインを介して伝送すると、単一波長を用いて１６ビットのデータ量を伝送する場合に比べ、１／２の伝送時間で済むことになる。これは波長が異なるパルスデータを同時に同じ光ファイバー等のバスラインを用いて伝送することが可能となることによる。この場合、光検出器７９は、波長λ１とλ２に感応する波長選択素子を内蔵しており、各波長選択素子からはそれぞれプリアンプおよびパラレル信号生成器に接続された８本のデータ線を介して受信データが出力され、メモリ素子や関連機器に向けてそれぞれ８ビットのデータが伝送される。つまり、２波長分のデータを一度に処理できるため２×８＝１６ビットのデータ量が１／２の時間で可能となる。同様に波長種を増すと、整数倍ビットのデータ量の増加が同一時間で可能となる。この場合、超微細構造素子７０により波長が異なるデータが同時に伝送されるため、一度に多量の情報伝達が可能であり、これによって非常に高容量の情報伝達素子として実現することができる。

【００２７】なお、回転ミラー７８に代えて、ハーフミラー或いは電気的に制御可能な偏光素子等を用いることもできる。また、光検出器７９は、各波長λ１，λ２に対応した独立の受光素子を２個用いて構成することもでき、その場合伝送データの位相を揃える必要は生ずるものの、出射光を分配するミラーは不要となる。さらに、超微細構造素子７０に２以上の棒状構造物を形成することにより、波長の異なる２以上のデータ列を同時に伝送することができる。

【００２８】なお、上記した本発明のエネルギービーム加工法に適用可能なエネルギービームとしては、高速原

子線，イオンビーム，電子線，レーザ，放射光，原子・分子線等が挙げられるが、それぞれの特徴は以下の通りである。高速中性のエネルギー粒子線である高速原子線は、金属や半導体或いは絶縁物などのあらゆる材料に対して適用でき、またイオンビームは、金属材料に対して非常に有効である。電子線は、照射と同時に試料に対して反応性のあるガスを導入することで、電子線が照射された場所のみ化学反応を生ぜしめることができる。また、放射光は、直接放射光のみを試料表面に照射して加工したり、或いは反応性ガス粒子との相互作用を利用して加工することにより、多彩な加工を可能にする。また、原子・分子ビームは、反応性ガス粒子の原子・分子ビームを照射することで低エネルギーのビーム加工を可能にする。このため、加工目的に応じて様々なエネルギービームを用いるとよい。

【００２９】

【発明の効果】以上説明したように、本発明によれば、被加工物の表面にエネルギービームを遮蔽する直径が０．１ｎｍないし１０ｎｍもしくは１０ｎｍないし１００ｎｍもしくは１００ｎｍないし１０μｍの微粒子を分散配置し、前記被加工物にエネルギービームを照射し、前記微粒子による遮蔽箇所を除く前記被加工物表面を加工するようにしたから、微粒子の寸法オーダーもしくは微粒子より微小な寸法オーダーでの微細加工が可能であり、従って従来のフォトリソグラフィ技術では困難であった超微細な加工構造物の製作が可能であり、また微粒子は被加工物の表面に付着させるだけでよいため、被加工物表面の粗さや平坦度に関係なく簡単に配置でき、従って表面の平坦度や粗さが粗悪な試料に対しては紫外光が均一に照射できないために均一で精度の良いレジスト膜付けが困難であったり、或いは加工面にしても平坦度のよい一面にしか適用できなかった従来のフォトリソグラフィ技術とは異なり、試料の局所や多面に超微粒子を分散配置して３次元構造の超微細加工が可能であり、特に指向性に優れたエネルギービーム加工による超微細領域における異方性加工との組合わせにより、加工精度を高めることができ、またレーザや磁界或いは電界等を作用させて微粒子を規則的に配置し加工することで、超小型の量子効果素子やメモリー素子や光素子の実現が可能となるなど、学術的にも産業的にも非常に意義のある加工法を提供することができる等の優れた効果を奏する。

【００３０】また、本発明は、エネルギービームの照射により、被加工物表面を深さ方向に加工する一方で前記微粒子を徐々に縮径加工し、該微粒子の遮蔽箇所に先細の棒状構造物を加工するようにしたから、例えばエネルギービームとして用いる反応性ガス粒子に対して反応性が低くスパッタ率も低い微粒子を用いることで、加工中の微粒子の形状変化を抑制し、被加工物を垂直壁に近い壁をもった棒状構造物に加工したり、エネルギービームとして用いる反応性ガス粒子に対して反応性が高くスパッタ率も高い微粒子を用いることで、加工中に微粒子を大きく形状変化させ、被加工物を円錐形状や角錐形状などの先細の棒状構造物に加工することができ、被加工物の表面に残留形成する構造物の形状を随意所望の形状に加工することができる等の効果を奏する。

【００３１】さらにまた、本発明は、エネルギービームを照射して微細加工を施した被加工物に、該被加工物に対し化学反応性を示すガス粒子を導入し、温度制御により該被加工物表面の化学反応性を制御し、該被加工物表面を等方的に加工するようにしたから、エネルギービーム加工を施した試料に、試料と反応性の高いガス例えば塩素ガスやフッ素ガス等の粒子を導入し、試料をヒータ或いは加熱ランプにより加熱することにより、方向性をもたない等法的加工を施すことができ、またこの等法的加工を施すことにより、残留微粒子だけでなく棒状構造物も一定比で縮小加工され、高速原子線のみによる加工と比較したときに、さらに微細な断面形状を有する棒状構造物に仕上げることができる等の効果を奏する。

【００３２】さらに、本発明は、エネルギービームとして、高速原子線又はイオンビーム又は電子線又はレーザ又は放射光又は原子・分子線を用いるようにしたから、エネルギービームとして例えば高速中性のエネルギー粒子線である原子線を用いた場合には、金属や半導体或いは絶縁物などのあらゆる材料に対して適用でき、またエネルギービームとして例えばイオンビームを用いた場合は、金属材料に対して非常に有効であり、さらにエネルギービームとして電子線を用いた場合には、電子線照射と同時に試料に対して反応性のあるガスを導入することで、電子線が照射された場所のみ化学反応を生ぜしめることができ、またエネルギービームとして放射光を用いた場合は、直接放射光のみを試料表面に照射して加工したり、或いは反応性ガス粒子との相互作用を利用して加工することにより、多彩な加工が可能であり、またエネルギービームとして原子・分子ビームを用いた場合には、反応性ガス粒子の原子・分子ビームを照射して低エネルギーのビーム加工が可能である等の効果を奏する。

【図面の簡単な説明】

【図１】本発明のエネルギービーム加工法の一実施例を示す工程図である。

【図２】本発明のエネルギービーム加工法の他の実施例を示す工程図である。

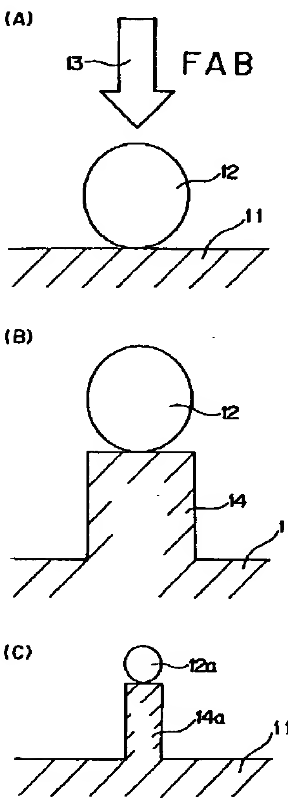
【図３】微粒子を二次元平面に規則的に配列してエネルギービーム加工を行った場合の被加工物の加工例を示す斜視図である。

【図４】微粒子を二次元平面に規則的に配列してエネルギービーム加工を行った場合の被加工物の他の加工例を示す斜視図である。

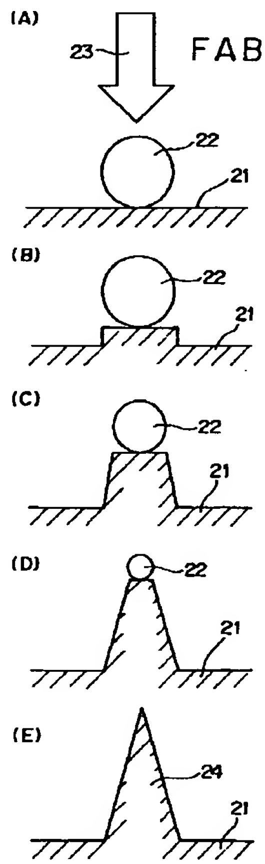
【図５】互いに斜交する二つの面に、複数の棒状構造物をそれぞれ所定の配置パターンでエネルギービーム加工した場合の被加工物の加工例を示す平面図である。

【図6】Ｓｉの超微細円錐構造物を前記第２実施例に示した工程を踏んで形成した被加工物の加工例を示す側面図である。
【図7】本発明のエネルギービーム加工法を適用して３次元の多面加工を施した超微細構造素子の加工例を示す図である。
【図8】従来のフォトリソグラフィ技術を適用した基板加工法の一例を示す工程図である。
【符号の説明】
１１，２１，３１，４１，５１，６１，７１　試料
１２，２２　微粒子
１３，２３　高速原子線
１４，２４　棒状構造物
３０，４０，５０，６０　被加工物
３４　列柱
４４　円錐
５４，７５　柱状構造物
６４，７４　円錐構造物
７０　超微細構造素子

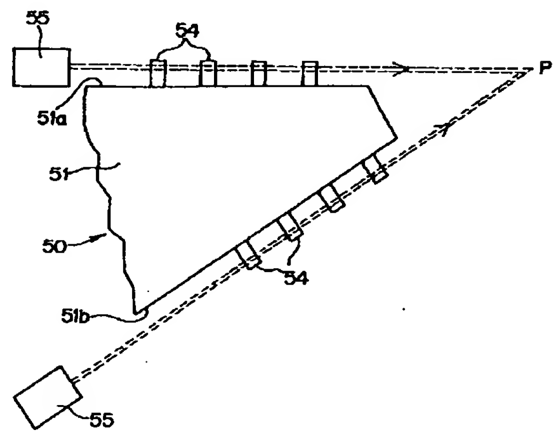
【図1】



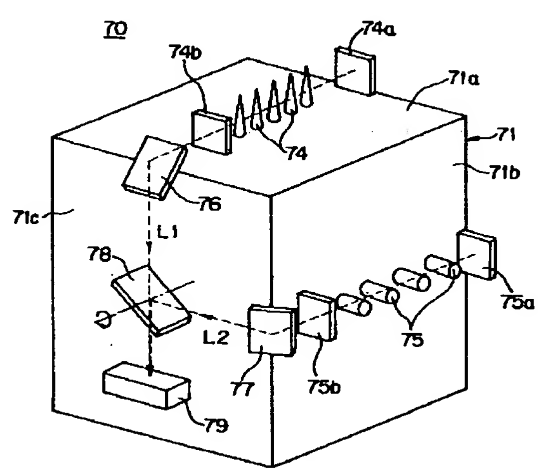
【図2】



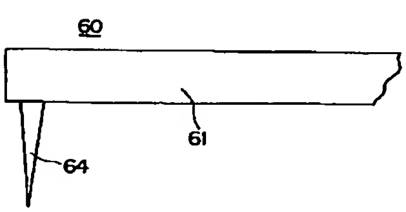
【図5】



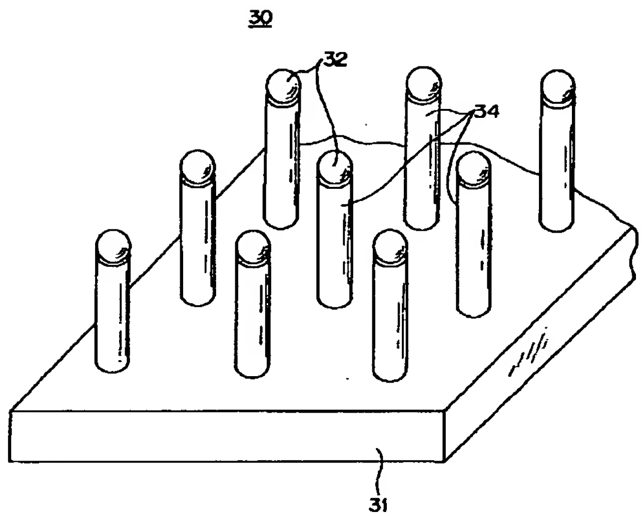
【図7】



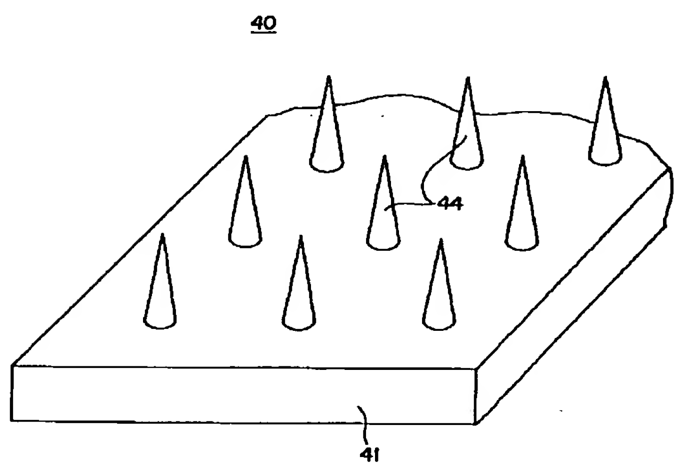
【図6】



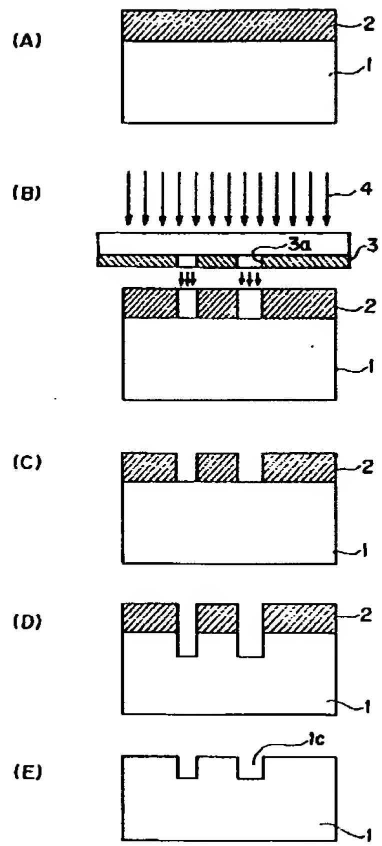
【図3】



【図4】



【図8】



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Date: 25 Feb 2003

To: Tom Robbins	**From:** Allan W. Olsen
Application/Control Number: 09/941,692	**Art Unit:** 1763
Fax No.: 202-721-8250	**Phone No.:** 703 306-9075
Voice No.: (202) 721-8200	**Return Fax No.:** 703 872-9310
Re: Copy of JP 08-328426	**CC:**

☐ **Urgent** ☒ **For Review** ☐ **For Comment** ☒ **For Reply** ☒ **Per Your Request**

Comments:
Mr. Robbins called the examiner Olsen to inform him that JP 08-328426 had been applied in the rejection of claims 40 and 41, however, the reference is not listed on any 892 or 1449 and the Office action of 2/12/2003 did not include a copy of the reference. Mr. Robbins requested a that a copy of the reference be faxed and he indicated that a remailing with a restart of the period for Applicant's response would not be necessary at this time. The examiner is including a copy of a machine translation of the Japanese language document.

Number of pages 22 including this page